AC NO: 150/5320-5B
DATE: 7/1/70

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: AIRPORT DRAINAGE

1. PURPOSE.

This circular provides guidance for engineers, airport managers, and the public in the design and maintenance of airport drainage systems.

2. CANCELLATION.

This publication cancels "Airport Drainage," AC 150/5320-5A, dated 1965.

3. REFERENCES.

The publications listed in the Bibliography, page 79, provide further guidance and technical information as may be required.

4. EXPLANATION OF REVISIONS.

In addition to minor changes in the text and figures, this advisory circular includes:

a. Reference to more detailed rainfall frequency charts now being published by the Weather Bureau for eleven Western States.

b. Addition of other fundamentals for use of Weather Bureau Technical Paper No. 40 and other technical papers and charts.

c. Emphasis on designing for direct runoff.

d. Information on grates and frames versus aircraft types, weights, and tire pressures.

e. A new section on flow in open channels.

f. Consideration of low head situations for grates in aprons.

g. A new section on culverts.

h. New recommendations for loads on structures in view of very heavy aircraft.

i. Additional emphasis on erosion control.

j. Information on permeability factors in subsurface drainage.

k. Addition of information on use of plastic filter cloths in subsurface drainage.

l. Some corrections to sample drainage system design data and to computations for ponding examples.

m. Revision of minimum pipe cover table including addition of corrugated aluminum alloy pipe.

n. Mention of need for pollution control.

o. Addition of a bibliography of reference material.

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Chapter 1. INTRODUCTION

1. CHARACTERISTICS OF AIRPORT DRAINAGE.

a. An airport should have smooth, well-drained operational areas with sufficient stability to permit the safe movement of aircraft under all weather conditions. The design of adequate drainage is important because it affects the stability and usability of extensive areas: yet, these areas are subject to varying soil and drainage conditions, and also have relatively flat grades.

b. The drainage system should be built before or during the grading operations because draining and grading are interrelated. A drainage system cannot be expected to function properly unless the airport area has been correctly graded to divert the surface runoff into the system. In the absence of adequate stabilization or pavement, drainage does not assure an all-weather airport, but it does shorten the interval of nonuse.

c. The large area that must be drained on an average airport requires an economically designed drainage system to realize the full value of the investment made. Sound engineering principles must be applied in the utilization of all available data, such as: topographic maps: soil reports; determinations of water tables; intensity, frequency, and duration of precipitation; climate and temperature reports; and nature of the area surrounding the particular site.

d. The topography of the site and the off-site areas affect the final layout of the runways, taxiways, aprons, and buildings. The location and size of these facilities will control the grading and the extent of drainage required. It is important that the grading of the airport be such that all shoulders and slopes drain away from runways, taxiways, and all paved areas. After final elevations on the airport have been determined, all surface flow of water onto the site must be intercepted and disposed of, any depressed or low spots on the site must be drained, and all surface runoff must be accumulated and directed into adequate outfalls.

e. Enough tests should be taken to identify all soil types because texture, permeability, and capillarity have a pronounced effect upon their drainability. Because of its effect on the stability of soils and on the ultimate design of the airport, the water table should be accurately determined over the entire area. When a high water table does exist, provision should be made for controlling or lowering it—or alternatively raising the pavement grades—see paragraph 21.

f. In designing a drainage system, it is important to determine expected precipitation at the airport site. Intensity-frequency or precipitation data may be obtained and developed from information in several publications as noted in paragraph 3.

g. Localized climatological data should be studied and advice sought on average frost penetration and recommended minimum depth of storm sewer installations for the area. For some localities, records of average accumulated snowfall would be pertinent to the drainage design.

2. PURPOSE OF AIRPORT DRAINAGE.

a. The purpose of airport drainage is to dispose of water which may hinder any activity necessary to the safe and efficient operation of the airport. The drainage system should collect and remove surface water runoff from each area, remove excess underground water, lower the water table, and protect all slopes from erosion.

b. Natural drainage normally does not meet these requirements. Constructed drainage facilities must be sufficient to provide for present requirements and any future enlargements of the system. This may mean the installation of a portion of a drainage system to supplement the natural drainage on the site or it may call for a complete system to drain the entire airport area. A proper understanding of all contributing drainage factors determines the extent of the facilities required on each particular airport.

c. An inadequate drainage system can cause serious hazards to air traffic at airports. The most dangerous consequences of inadequate drainage systems are saturation of the subgrade and subbase, damage to slopes by erosion, loss of load-bearing capacity of the paved surfaces, and excessive ponding of water.

d. Aprons and other pavement should be sloped away from buildings so that there will be no possibility of fuel spillage flowing toward buildings.

Chapter 2. HYDROLOGY

3. RAINFALL.

a. The determination of the amounts of rainfall and runoff to be used as a basis for design of a drainage system is the primary step to be considered by the designer. The rate of storm runoff which will flow into the system must be established in the preliminary design stage. At some locations this may involve rainfall plus melting snow or ice.

b. The importance of the rainfall-intensity factor is well known to drainage engineers, particularly in its relationship to total runoff. Investigations have shown that results of studies regarding the probable intensity, frequency, and duration of rainfall in particular locations are more likely to be correct and conservative if they are obtained from the records of many stations rather than from the record of one station. Single stations seldom give a true picture of the rainfall-frequency regime for various locations. The use of many stations in a region to determine the pattern and value of the rainfall-frequency values tends to minimize the limitations of a small sample in both time and space.

c. Many investigations and studies have been conducted to find a basis for making reasonable estimates of the intensities, frequencies, and durations of rainfall for different locations. A previously used publication by D. L. Yarnell, "Rainfall Intensity-Frequency Data," has now been replaced by more recent studies. Rainfall-frequency data for the United States, Puerto Rico, the Virgin Islands, Hawaii, and Alaska can be obtained from a series of Weather Bureau Technical Papers. Data for the conterminous United States are given in ESSA-Weather Bureau Technical Paper No. 40, "Rainfall Frequency Atlas of the United States," dated May 1961. Technical Paper No. 40 is intended as a convenient summary of empirical relationships, working guides, and maps, useful in practical problems requiring rainfall-frequency data. It is an outgrowth of several previous Weather Bureau publications on this subject and contains an expression and generalization of the ideas and results in earlier papers. It is divided into two parts:

(1) The first part presents the rainfall analyses. Included are measures of the quality of the various relationships, comparisons with previous works of a similar nature, numerical examples, discussions of the limitations of the results, transformation from point to areal frequency, and seasonal variation.

(2) The second part presents 49 rainfall-frequency maps based on a comprehensive and integrated collection of up-to-date statistics, several related maps, and seasonal variation diagrams. The rainfall-frequency (isopluvial) maps are for selected durations from 30 minutes to 24 hours and return periods from 1 to 100 years.

Rainfall-frequency data for Puerto Rico and the Virgin Islands, Hawaii and Alaska can be obtained from ESSA-Weather Bureau Technical Papers No. 42, "Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and the Virgin Islands, "dated 1961; No. 43, "Rainfall-Frequency Atlas of the Hawaiian Islands," dated 1962; and No. 47, "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska," dated 1962, respectively.

d. The preferred source of precipitation-frequency information for the eastern two-thirds of the conterminous United States is ESSA-Weather Bureau Technical Paper No. 40. Rainfall-frequency data for the eleven Western States can be obtained from the physiographically adjusted precipitation-frequency maps currently being prepared by the ESSA-Weather Bureau. These maps have been completed for the States of Arizona, New Mexico, Colorado, Utah, Wyoming, Montana, Idaho, Washington, and Oregon. Maps for Nevada and California are currently being prepared and should be available shortly. The maps for the Western United States are only for the 6- and 24-hour duration values and relations given in Technical Paper No. 40 must be used to obtain the values for the shorter durations (see paragraph g below). Rainfall-frequency values for Puerto Rico and the Virgin Islands, Hawaii and Alaska can be obtained from ESSA-Weather Bureau Technical Papers Nos. 42, 43, and 47, respectively. It should be recognized that there may be some locations where the values from the generalized charts may be either an over or an underestimate. If the engineer suspects this to be the case, he should investigate all possible sources of data for additional information to verify or revise the published values. Possible data sources are the local ESSA-Weather Bureau Office, the State Highway Office, State Hydrographers Office, City Engineer's Office, and perhaps local drainage districts or utility companies. Such locally derived data should not be used to override the data from the Weather Bureau Technical Papers unless there is ample evidence that the latter data is clearly not applicable to the local situation.

e. The rainfall intensity-duration curves required for design purposes, in the conterminous United States, can be derived from the charts in Technical Paper No. 40. Figures 1 to 5 are examples of the charts in that paper. It is not intended that these figures be used for determining intensity as the scale was kept quite small for illustration purposes. Return periods of 2, 5, and 10 years are sufficient for airport drainage calculations and sufficient for comparisons between such periods. To construct intensity-duration curves such as shown in Figure 6, begin by spotting the airport location on the 30-minute, 1-hour, and 2-hour charts for 2, 5, and 10 years in Technical Paper No. 40. Then read the intensities by scaling between the isolines, linear interpolation between adjoining isolines is sufficient. For example, the 5-year, 30-minute rainfall chart (Chart 3) reveals that the intensity at Chicago would be 1.37 inches. This must be converted to a 1-hour basis for curve plotting purposes, therefore, the scaled quantity must be multiplied by the ratio between 1-hour and the ½-hour duration ($1.37 \times (60 \div 30) = 2.74''$). Plot this intensity on coordinate paper (using inches per hour as ordinates and duration in minutes as abscissas). Similarly, scale the intensity for Chicago for a 1-hour rainfall to be expected once in 5 years from Chart 10, for a 2-hour rainfall from Chart 17, and convert the latter value to a 1-hour basis. As Technical Paper No. 40 does not have short-duration rainfall charts, i.e., for 5, 10, and 15 minutes, it is necessary to use the Weather Bureau developed relationship between a 30-minute rainfall on the one hand and 5-, 10-, and 15-minute amounts on the other. This relationship is as follows:

Duration (minutes)	5	10	15
Ratio	0.37	0.57	0.72

Thus, the Chicago 30-minute amount of 1.37 can be reduced to a 5-minute amount by multiplying 1.37 by 0.37 or $1.37 \times 0.37 = 0.51''$; similarly, $1.37 \times 0.57 = 0.78''$ for the 10-minute amount, and $1.37 \times 0.72 = 0.99''$ for the 15-minute amount. Then convert these values to a 1-hour basis as described above. Accordingly, the 5-, 10-, 15-, and 30-minute, 1-hour, and 2-hour intensities give 6 points on the coordinate paper and a smooth curve can be drawn through the points to construct the 5-year curve. This curve will indicate the intensity of rainfall to be expected for any time interval from 5 minutes to 2 hours for a storm that might occur once in 5 years. The same procedure should be followed to construct curves for 2 and 10 years. Figure 6 is a graph exemplifying this procedure.

f. Similar procedures can be followed in Puerto Rico and the Virgin Islands, Hawaii, and Alaska, using charts from the appropriate Weather Bureau Technical Papers to obtain values for 30 minutes, 1, and 2 hours. The 5-, 10-, and 15-minute values can be approximated using the ratios with 30-minute rainfall values cited earlier.

g. The more detailed rainfall-frequency charts for the 11 Western States, referred to in paragraph d above, should be used to obtain the rainfall intensities for the more variable conditions found in the mountainous areas of Western United States. These studies provide detailed maps which depict the variation in rainfall-frequency values in this portion of the country. These maps were developed to depict the rainfall-frequency values for average conditions along orographic barriers and in mountain valleys. At some locations, where the topography departs significantly from average conditions, values determined from the generalized chart may be either an under or overestimate. Locally available data for these locations could be considered by the engineer to modify values obtained from the generalized charts. Such locally derived data should not be used, however, unless there is ample evidence to show that the local situation insists that such data are more applicable than that in the generalized charts. The following procedure will need to be used to convert the information in the charts for the 11 Western States to a more useable form. As the charts provide values for only the 6- and 24-hour durations, it is necessary to compute values for the shorter durations for our purposes. This can b edone by using Figure 2 of Technical Paper No. 40. (First note, however, that these charts show values in tenths of an inch, so they must be converted to inches.) For example, read the 5-year, 6- and 24-hour amounts for the airport location from the charts and plot these amounts on Figure 2. Lay a straight-edge across the two points and read the values for 1- and 2-hour durations at the proper intersections. Estimate the 30-minute rainfall by multiplying the one-hour value by 0.79. Then proceed to convert the 30-minute value to 5-, 10-, and 15-minute values by using the ratios given in paragraph e above. Then convert the values to a 1-hour intensity and construct a 5-year curve in the manner described in paragraph e.

h. The use of the data, developed as described in either paragraph e or g above, is taken up later in Chapter 5 and is the basis for estimating runoff.

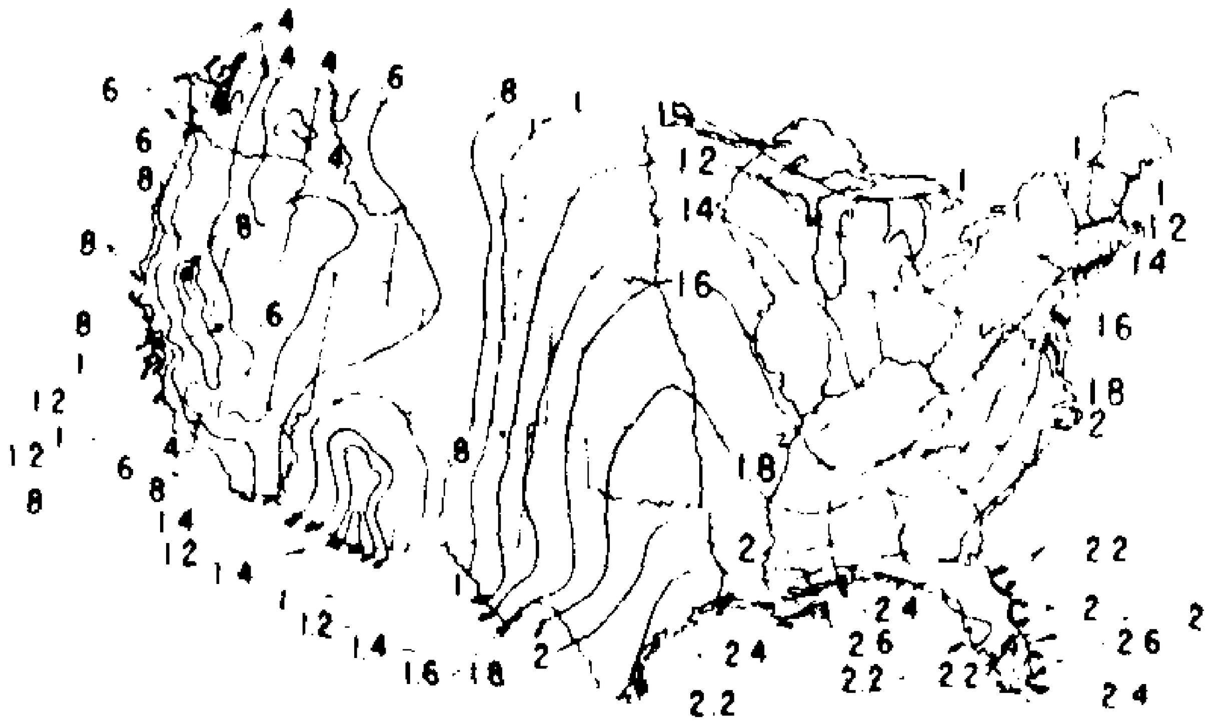
Thirty-minute rainfall, in inches, to be expected once in 5 years.

Figure 1

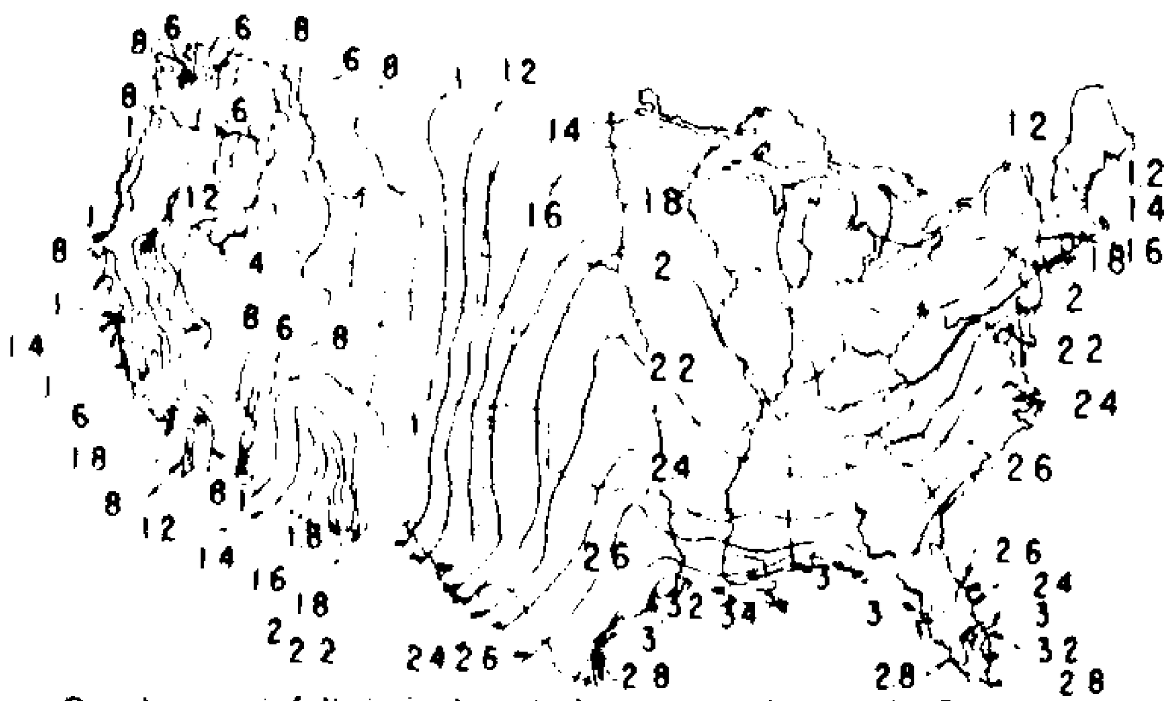
One-hour rainfall, in inches, to be expected once in 5 years

Figure 2

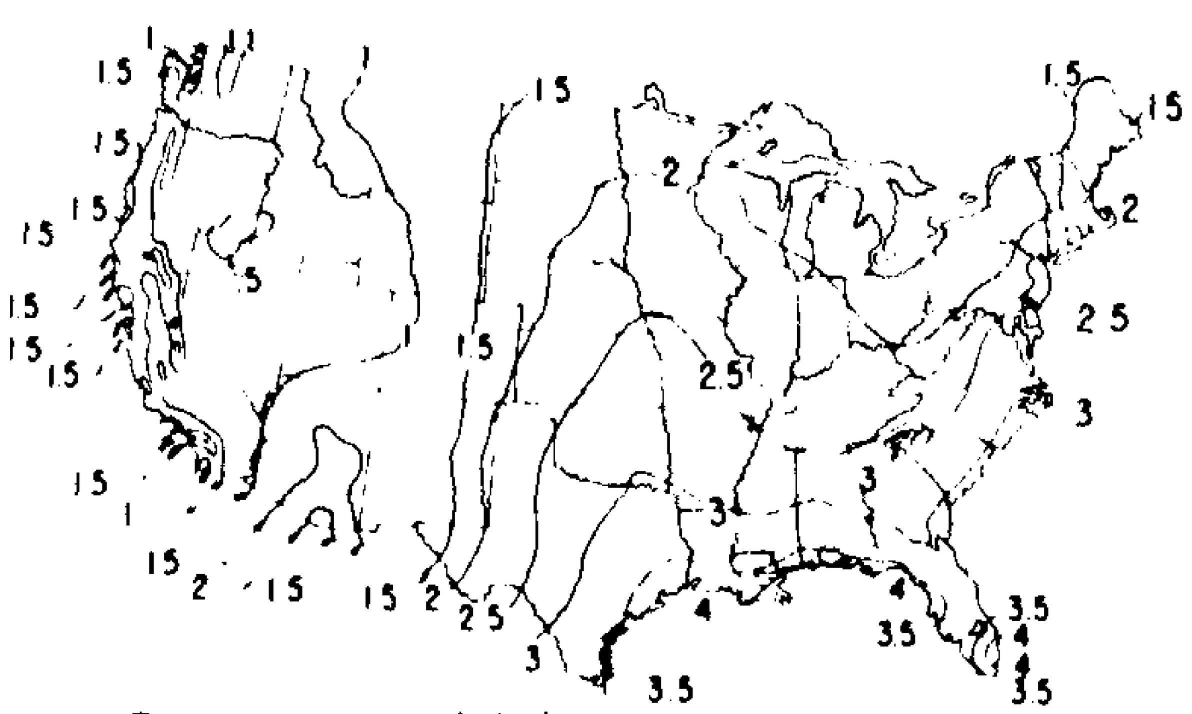
Two-hour rainfall, in inches, to be expected once in 5 years

Figure 3

NOTES

THE WEATHER BUREAU DEVELOPED RELATIONSHIPS FOR SHORT DURATION RAINFALLS. THE AVERAGE RELATIONSHIP BETWEEN 30 MINUTE RAINFALL ON THE ONE HAND AND 5-, 10-, AND 15-MINUTE RAINFALL ON THE OTHER CAN BE OBTAINED FROM THE FOLLOWING

DURATION (MIN)	5	10	15
RATIO	0.37	0.57	0.72

THUS A GEOGRAPHICAL POINT ON FIGURE 1 WHICH INDICATES A THIRTY MINUTE RAINFALL OF 1.6 INCHES ONCE IN 5 YEARS MAY BE REDUCED TO 5 MINUTES BY MULTIPLYING 1.6 BY 0.37 = .592 INCHES OR 10 MINUTES AS 1.6 BY 0.57 = .912 INCHES OR TO 15 MINUTES AS 1.6 X 0.72 = 1.152 INCHES.

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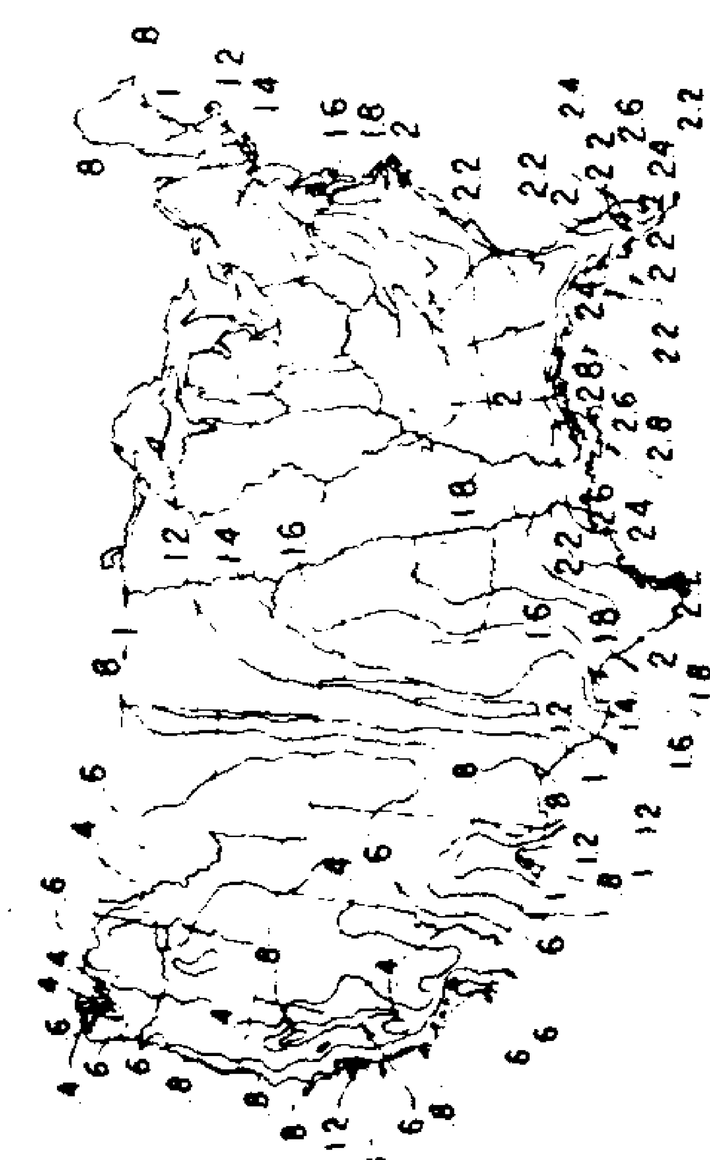
IF ACTUAL WEATHER BUREAU RECORDS OR SUPPLEMENTAL RECORDS ARE NOT AVAILABLE FOR THE POINT IN QUESTION THEN THE CHARTS IN THE TECHNICAL PAPER NUMBER 40 "RAINFALL FREQUENCY ATLAS OF THE UNITED STATES" MAY BE USED TO CONSTRUCT INTENSITY CURVES SUCH AS SHOWN IN FIGURE 6. INDEED FIGURES 1, 2, 3, 4, 5 WERE CONSTRUCTED FROM TECHNICAL PAPER NUMBER 40 AND SERVE TO ILLUSTRATE THE METHOD OF DEVELOPING AN INTENSITY-DURATION CURVE OR CURVES. FIRST SPOT THE AIRPORT LOCATION UNDER CONSIDERATION ON FIGURE 1, (30 MINUTE RAINFALL, INCHES, TO BE EXPECTED ONCE IN 5 YEARS) LOCATING THE POINT AS ACCURATELY AS POSSIBLE. THEN SCALE THE INTENSITY FOR THE POINT IN QUESTION BY INTERPOLATION BETWEEN THE TWO ISOHYETAL LINES ON EITHER SIDE OF THE POINT. TO ILLUSTRATE, THE INTENSITY SCALED FROM FIGURE 1 IS FOUND TO BE 1.36 INCHES AT CHICAGO; THIS IS FOR A 30 MINUTE RAINFALL TO BE EXPECTED ONCE IN 5 YEARS. THIS INTENSITY NEEDS TO BE CONVERTED TO A 1-HOUR BASIS FOR PLOTTING PURPOSES.

THUS THE SCALED QUANTITY OF 1.36 INCHES MUST BE MULTIPLIED BY 60 ÷ 30 OR 2 RESULTING IN 1.36" X 2 = 2.72". PLOT THIS INTENSITY ON COORDINATE PAPER (USING INCHES PER HOUR AS ORDINATES AND TIMES IN MINUTES AS ABSCISSAS). SIMILARLY SCALE THE INTENSITY FOR CHICAGO FOR 1-HOUR RAINFALL TO BE EXPECTED ONCE IN 5 YEARS FROM FIGURE 2 AND FOLLOW THE ABOVE PROCEDURE. THEN USE FIGURE 3 FOR TWO HOUR RAINFALL.

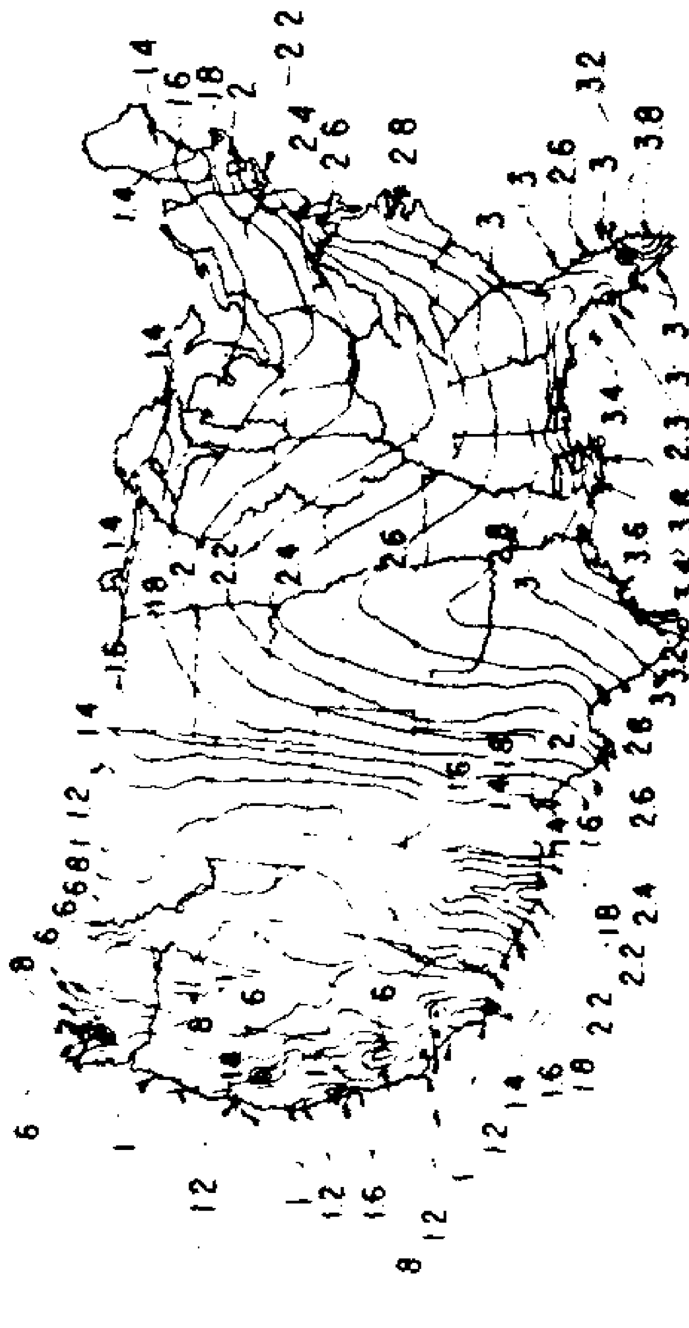
ALSO, CONVERT THE 30 MINUTE INTENSITY TO 5-, 10-, AND 15 MINUTE INTENSITIES AS INDICATED ABOVE, CONVERT TO 1 HOUR BASIS AND PLOT. FIGURE 6 ILLUSTRATES 2, 5 AND 10 YEAR INTENSITY DURATION CURVES CONSTRUCTED IN THIS MANNER

FIGURES 1, 2, 3. Rainfall frequency maps.



One-hour rainfall, in inches, to be expected once in 2 years

Figure 4



One-hour rainfall, in inches, to be expected once in 10 years.

Figure 5

FIGURES 4 and 5. Rainfall frequency maps.

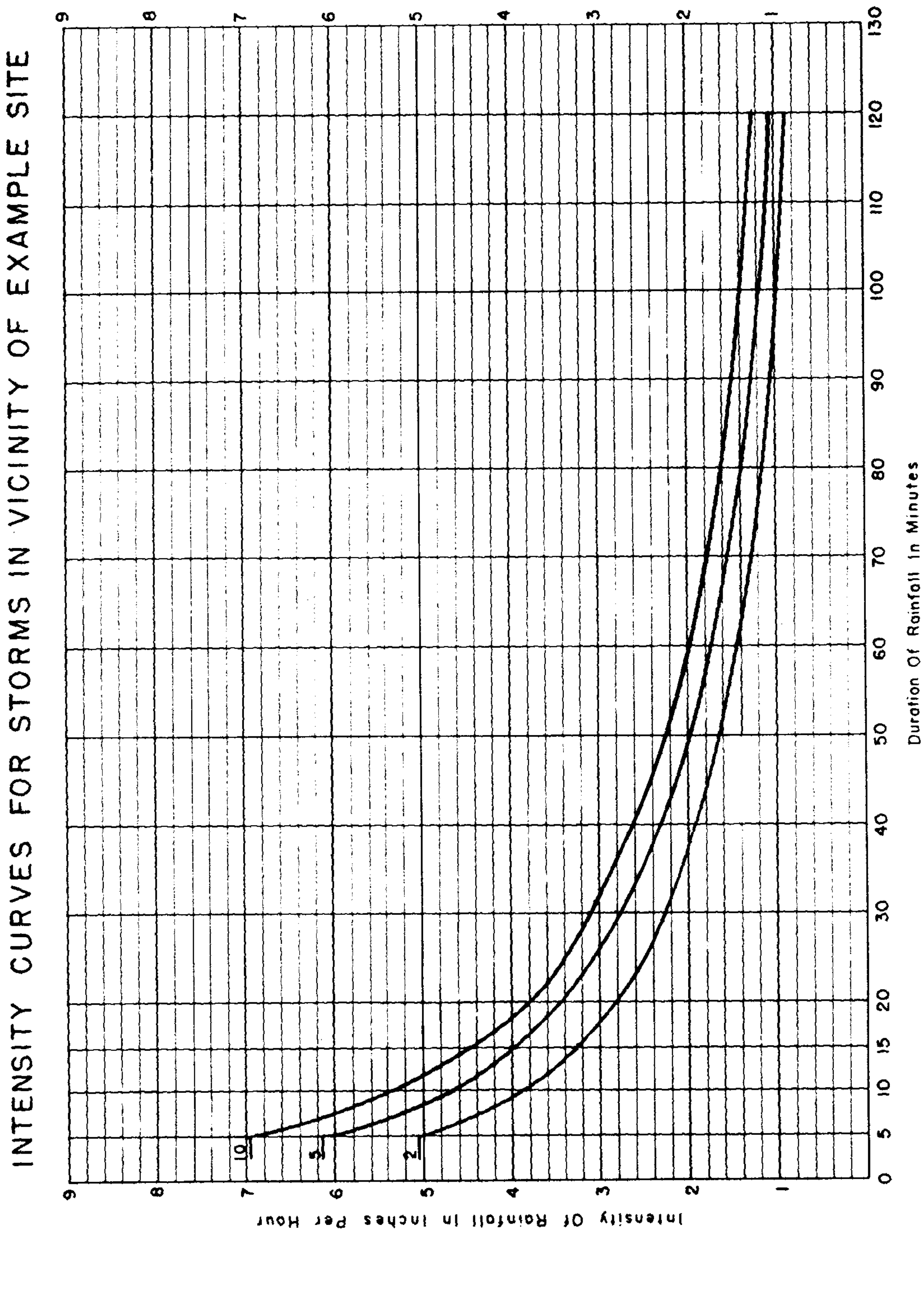


FIGURE 6. Intensity curves for storms in vicinity of example site.